VI. "On the Causes of various Phenomena of Attraction and Adhesion, as exhibited in Solid Bodies, Films, Vesicles, Liquid Globules, and Blood-Corpuscles." By RICHARD NORRIS, Esq., Birmingham. Communicated by Dr. SHARPEY, Sec. R.S. Received August 28, 1862.

It has long been observed that solid bodies floating on liquids possess the property of modifying the figure of the surface of the liquid; thus pieces of tinfoil or greased bodies depress the liquid around them, while many others by the exercise of an attraction for its particles elevate it, giving rise to small mounds of liquid bounded by concave lines. It has also been observed that likes attract likes and are repelled by unlikes, *i. e.* bodies having like or unlike powers of altering the figure of the surface. These phenomena are generally admitted to depend for their existence on the combined forces concerned in capillary attraction. The following experiments are arranged to show that these effects of attraction are not peculiar to floating bodies or to bodies partially immersed, and that the only requirement is that liquid should be associated with the bodies in which the movement occurs.

Exp. 1. Let two balls of sealing-wax, or other material of greater specific gravity than water, be suspended by hairs in such a manner that they will both be partially immersed in water to an equal extent, the points of suspension being at a little distance apart, and the suspending hairs consequently parallel. When brought within the proper range, they will attract each other in the same manner as the floating bodies. In doing so they necessarily describe a small arc of a circle, of which the suspending hair is the radius, and have therefore not simply moved towards each other in a horizontal line, but have been raised to a higher level.

Exp. 2. Let two small sheets of microscopic glass be applied to each other by their lower edges so as to form an acute angle like the letter V, and let them be supported in this position by pins. On placing a drop of water in the angle, the plates will be drawn together and cohere by their surfaces.

Exp. 3. Suspend moveably, by means of a thread passing over a pulley and a small counterbalancing weight, a horizontal cork disk,

from the under surface of which a drop of water is hanging. On a support beneath, formed by three upright pins, place a small piece of paper or thin glass, on the surface of which there is also a drop of water. On depressing the disk till the two drops of water touch each other, the paper or plate will be instantly drawn up to it; or if the plate at the bottom be heavier than the disk, the latter will be drawn down.

Exp. 4. If a film of wetted collodion be partially stripped from a glass plate, on being loosed it immediately flies back to its original contact. The same effect may be observed if thin paper be wetted and spread on a smooth sheet of glass, or be laid on the surface of water.

Exp. 5. Take two wine-glasses and dip their mouths into a strong solution of albumen; by a little dexterity two delicate convex films will be obtained. On applying the most elevated points of the convexities to each other, the films will be attracted and reduced to plane surfaces strongly adherent to each other. The permanency of the films enables the experiment to be repeated several times in succession.

Exp. 6. When a soap-bubble is allowed to fall on an irregular surface, such as a piece of lint or flannel, it maintains its spherical shape; but if a smooth surface, such as a sheet of glass, be brought into slight contact with it, the wall of the bubble will be immediately attracted and flattened out upon it. In like manner, when two bubbles come into contact by their convex surfaces and cohere, the cohering surfaces become flattened; and bubbles in a group cohere by plane surfaces.

Among other natural bodies, blood-corpuscles present certain peculiarities of arrangement when withdrawn from their proper channels; thus when a minute drop of mammalian blood is placed upon a glass plate, the disks arrange themselves into rouleaux of well-known form. They become attached to each other in this case by their biconcave surfaces. They may also cohere by the edge or circumference, and give rise to a tessellated appearance. This latter arrangement is most easily obtained by placing a minute drop of blood on the under surface of a thin piece of microscopic glass so as to be viewed through it; the blood being in a dependent position. A third mode of union occurs when gum, gelatine, mucilage of linseed, or very thick solution

of starch is added to blood. The corpuscles cohere more closely and tenaciously than in either of the other conditions. They may be said to *blend* with each other, inasmuch as they form homogeneous masses. If the solution of gum or gelatine be added to the blood subsequently to the occurrence of the modes of arrangement previously described, in such a manner as not to disturb them, the already adherent corpuscles will cohere more closely, and the outlines of the corpuscles will be rendered less apparent, till at length homogeneity of appearance results. The same effect takes place if a drop of blood be allowed spontaneously to thicken, but rarely to such an extent as on the addition of gum, gelatine, &c.

This last mode of arrangement includes both the former conditions, inasmuch as the corpuscles cohere firmly not only by their biconcave surfaces but by their edges also.

The first mode, or the formation of rouleaux, may be closely imitated by preparing a number of small disks of cork so poised as to float in the vertical position; however carelessly these disks may be thrown into water, they will be found in a few moments to have arranged themselves into rouleaux after the manner of the blood-disks.

If a collection of blood-corpuscles cohering in the second mode be compared with the manner in which bubbles group themselves, as already described, the similarity will be allowed to be very striking.

From the marked analogy existing in their modes of arrangement, a suspicion naturally arises that the blood-globules are influenced by the same laws as the bubbles and cork-disks. A more critical investigation, however, proves that the phenomena, although allied, possess well-marked distinctions. The capillary action leading to adhesion, as exhibited in the cork-disks and bubbles, is not possible if these bodies are completely submerged in liquid; but experiments carefully performed with the blood-globules demonstrate that both the formation of rouleaux and the peripheral adhesion may take place under circumstances in which it is absolutely certain that each individual corpuscle is completely submerged. Thus if we take two pieces of microscopic glass, and, placing them in contact, press them firmly together and maintain them in opposition by a strong pair of pincers, we shall still have a capillary space between them which will draw in

a thin layer of blood, the corpuscles of which will form themselves into the most perfect and beautiful rouleaux.

The plasticity of the blood-corpuscle is unrivalled by any other physical body. It will assume all sorts of protean shapes under the slightest influences. Elongating to a mere thread, it will pass through a narrow chink; it will wrap itself round an acute projecting angle, or protrude feelers and tails under the influence of currents. In its natural state it possesses sufficient elasticity to resume its original shape on the cessation of modifying influences; but when gum or gelatine has been added, or when the plasma has been permitted to thicken spontaneously, the corpuscle retains any form it may have assumed, till again altered by some fresh influence.

The only artificial body capable of simulating the visible modifications of the blood-corpuscle is an extremely delicate, moderately filled vesicle.

The variations in its behaviour appear to be due to the degree of distention or flaccidity, which are doubtless under the influence of diosmosis.

When the corpuscles are apparently fused together, as after the addition of gum, the mass runs about like a thick liquid. Parts not previously in contact coalesce intimately with each other. Under the influence of currents, these masses stretch at certain points into fine threads, consisting of a single file of corpuscles, each corpuscle being elongated to its utmost, and finally sever at the natural junction of a single corpuscle with its fellow, the two stretched portions receding again into their respective masses.

Familiarity with the various conditions which the blood-corpuscles assume, and the analogous effects which take place in globules of homogeneous liquids, leads irresistibly to the conclusion that, on account of their great plasticity and the extreme tenuity and pliancy of their enclosing membrane, the blood-corpuscles are, under certain circumstances, subject to the law of cohesive attraction, in the same manner as these globules; and that, as with the latter so with the blood-corpuscles, changes in the character of the surrounding liquid determine the facility with which this law may come into operation.

If, as is well known, we place on a non-metallic surface small portions of liquid mercury, they will retain their spheroidal shape; and if any two of them be made to touch, they will be attracted to

each other, and one larger globule will result. If for the mercury we substitute water, using paper or metal as a support, we may get partial spheroids, which, being increased by repeated small additions till they touch each other, immediately coalesce, forming a semi-ovoid mass, instead of a sphere as in the case of the mercury. Mercury containing other metals in solution acts like the water.

Again, if a small quantity of chloroform or bisulphuret of carbon be poured into water, the greater portion will sink to the bottom of the water in globules of various sizes. The portion which floats may also be driven below the surface by striking it from above. These globules, when in contact, act precisely as the mercurial globules, *i. e.* blend with each other. They frequently adhere to the bottom of the vessel; and on an attempt being made to move them, tail-like appendages are produced. Creosote, castor oil, and the ethereal oil of male fern, all give permanent globular masses when forced below the surface of water. By agitation of the water, the latter globules may be elongated into threads from half an inch to an inch in length, and again resume their spheroidal shape. If in the process of elongation the thread be broken through, two spheroids result. If, instead of water, we use in these experiments a solution of soap, whatever form is given by agitation to the masses of oil is retained, and they possess no power whatever to blend with each other—the cohesive power is completely restrained.

If a portion of the same oil be shaken with water, we get a number of minute globules; and by placing them in a cell under the inch power of the microscope, we observe they possess little tendency to coalesce after the type of the chloroform; but if a portion of gum solution be poured into the cell, the process of incorporation commences immediately, and proceeds with rapidity. When these globules are formed in thick syrup, they exhibit a very great tendency to combine; but if to the syrup a little thick gum be added, this action is wholly prevented; neither do they adhere to each other when in contact.

If we mix three parts of a solution of 5 grains of gelatine in 1 drachm of water with 1 part oil of male fern, forcibly shaking them together in a test-tube, and draw a little of the mixture between two glasses in contact, we obtain numbers of globules about the size of the blood-corpuscles, and many much smaller. These globules

will be seen to possess the power of adhering to each other in groups and rows; and on a closer examination the cohering parts will be observed to have undergone a mutual flattening, just as in the case of the corpuscles and bubbles before mentioned.

We find then that the blood-corpuscles, while beneath the surface of the serum, adhere to each other, sometimes by their biconcave surfaces, so as to form rouleaux, sometimes by their peripheries, and sometimes in both ways simultaneously. They adhere also to foreign substances with which they come in contact, and on which they rest; and then currents in the liquor sanguinis give rise to tail-like processes. An adherent mass of corpuscles is capable of being elongated, and frequently gives way in the centre, when the two parts recede into their respective masses.

These effects occur contemporaneously with changes in the liquor sanguinis. In the normal state of this liquid, the corpuscles have no tendency to cohere; but the slightest modification of it, even while within the vessels, confers cohesive power on the white corpuscle; and the further alteration which occurs in blood taken from the body disposes the red disks to arrange themselves in rouleaux. When the liquor sanguinis is further altered by the addition of colloid substances, or allowed to modify itself spontaneously, the corpuscles become less elastic, and evince a great tendency to float with their surface upwards, and hence to cohere by their edges.

The attraction being proportionate to the amount of surface in contact, when the disks are free to move in the vertical position, and the tendency to cohesion is but moderate, they arrange themselves by their plane surfaces as the cork-disks do, not because the edges of the disks have no attraction for each other, but the planes offering a larger surface of attraction, this position is not so easily disturbed by currents in the serum. That this is the fact may be learned from the circumstance that when the plane surface of a cork- or blood-disk comes in contact with the side of a rouleau, it becomes as firmly fixed as if applied to the plane of its fellow. Every specimen of blood offers numerous instances of this kind.

These then being some of the peculiarities of blood-corpuscles, we learn, on the other hand, that globules of homogeneous liquids attract and become incorporated with each other when submerged in other liquids, being, like the blood-corpuscles, influenced in this

respect by variations in the surrounding medium. They may also, by disturbances of this medium, become elongated; and if the elongated mass severs, each portion falls back into itself and becomes an independent globule. They also become adherent to the solids which they touch, and exhibit tail-like processes. It will be universally admitted that these latter phenomena depend on cohesive attraction. Compared with the blood-corpuscles, these bodies are rigid and unyielding; how much more readily may we therefore ascribe the like effects observed in the former to the same cause.

It has been urged that nothing approaching to the character of an attractive influence has ever been observed with the blood-disks; but it must be remembered that the attraction of cohesion could not be indicated by motion between corpuscles at perceptible distances, but could only take place when the particles of the bodies were so closely applied to each other as to be within the radius of the sphere of molecular influence; and it is only under certain special circumstances that such an attraction could be even inferentially visible.

I have repeatedly observed such an attraction exercised among corpuscles under the only circumstance in which the observation is possible. After the addition of gum or gelatine to the blood, and the cessation of the consequent disturbance, there will still be many individual corpuscles and little circular masses floating sluggishly and unattached in the serum. After a time some of these will come in contact with each other at one point in their circumference; and if the disturbance in the liquor sanguinis is very slight, they will cohere at this point, and then will be seen to become gradually applied to each other for half their circumference. This is an action which can readily be understood as the successive operation of molecular attraction on the particles of the corpuscles immediately contiguous to those in absolute contact, but can receive no explanation on the hypothesis of adhesiveness. The best mode of observing this important phenomenon is to draw the mixture of gum and blood between two glasses in contact.